their movement rates (*See Figure 1,previous page.*). The final analysis of these data will enable information on movement rates and the position of fishes to be overlaid on habitat topography and connectedness as well as biological characteristics such as kelp density.

In addition to contributing to ecological understanding about fish movements in kelp forest landscapes, this project has important societal implications. Marine protected areas (MPAs) have received increased attention as a tool to manage and conserve marine resources – by protecting habitat and ecological function and supplementing traditional fisheries management by protecting a subset of a fishery stock from exploitation. However, predicting how effective a reserve will be requires an understanding of the relationship among the size and shape of a reserve, fish home ranges, and habitat complexity. This study represents one of a handful of studies that can explicitly link habitat use and movement of individuals to remotely sensed habitat maps within and adjacent to existing marine reserves. The development of such an approach and the information gleaned from this study are fundamental to the sound development and evaluation of MPAs for reef fish conservation throughout coastal, temperate oceans.

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Habitat Mapping: Characterizing Sanctuary Seafloors

Terrestrial landscapes have been well mapped and documented. Maps are available that provide a wealth of spatial information on landscape features (e.g., elevation, slope) and composition (e.g., rivers, mountains, farms, cities). We also have maps and information on the distribution of the flora and fauna that inhabit these different landscapes. Consequently, one might expect similar maps and information to be available for our marine environment. Alas, we know relatively little about the habitats and organisms that exist on our seafloors.

A key mission of the national marine sanctuaries is to understand and manage the marine environment within sanctuary boundaries. This requires a sound knowledge of the composition and complexity of the marine environment, its habitats, and the organisms that occur there.

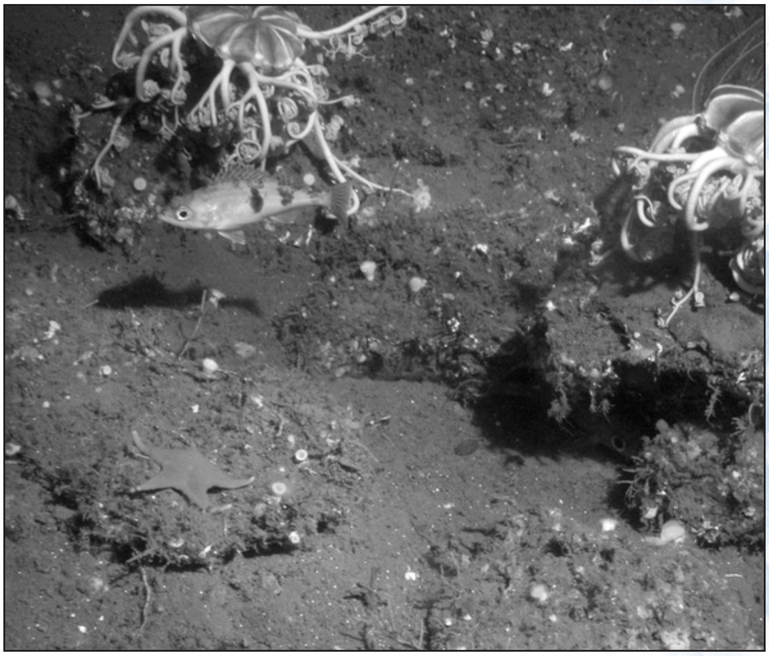


Figure 1. Low-lying cobble habitats inhabited here, 110 meters off Point Pinos, by basket stars (Gorgonocephalus eucnemis), vermilion star (Mediaster aequalis), and half-banded rockfish (Sebastes semicinctus)

In April 2004 a team of scientists from the U.S. Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA) Sanctuaries, and NOAA Fisheries collaborated on a twenty-day research cruise to map and describe the seafloor across the continental shelf from the northern reaches of the Cordell Bank National Marine Sanctuary (CBNMS) to the southern reaches of Monterey Bay. The survey's goals were to map the geology, habitat, and biodiversity within regions of the three adjacent national marine sanctuaries: Monterey Bay (MBNMS), Gulf of the Farallones (GFNMS), and Cordell Bank. This project aimed to build on existing data but in many places provided our very first glimpses of the seafloor.

Research surveys were conducted from April 1 to April 21 aboard the 225-foot NOAA ship *McArthur II*. Our research team, including Roberto Anima, John Chin, and Fred Payne (USGS); Dale Roberts and Dan Howard (CBNMS); and Jean de Marignac and Erica Burton (MBNMS), worked day and night to collect information on the seafloor in the three sanctuaries. During the day, side scan sonar was used to map seafloor geology over large areas. At night, a towed camera-sled was used to film these habitats and document the organisms living there. USGS scientists used a Klein 3000 side scan sonar system to acoustically image several previously unmapped sections of the seafloor within each sanctuary (e.g., Pescadero Reef in the MBNMS) and to extend coverage from earlier missions (e.g., Fanny Shoals in the GFNMS). Hundreds of hours of video footage were then collected from multiple transects with the towed camera, providing a wealth of information about the types of habitat and life found on the seafloor and about the distributions of geological features, habitats, and organisms across and along the shelf.

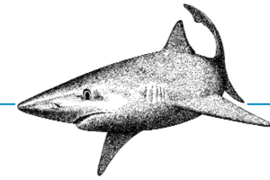
A variety of seafloor habitats and marine creatures were identified within the sanctuaries. For example, sand-wave habitats were verified in areas around Point Pinos and were occupied by sand dabs and schools of juvenile rockfish. Sediment-ripple habitats were common across regions of the shelf and were often densely populated with white brittle stars with their bodies buried in sediment. Low-lying cobble habitats were verified along the mid-shelf region south of Monterey Canyon and were occupied by encrusting organisms such as basket stars, sponges, and gorgonian corals and by fishes such as the half-banded rockfish, *Sebastes semicinctus* (*See figure 1.*). High-relief bedrock habitats, although less common on the mid- to outer shelf, were also surveyed and characterized. These habitats were occupied by encrusting invertebrates, vase sponges, large anemones, gorgonians, and many rockfish species.

An integral aspect of this project involved the development of a rapid-data-entry protocol whereby seafloor categorizations and descriptions were recorded in real time. Although requiring effort, the protocol enables seafloor data to be processed while at sea, including the production of maps within hours of data collection. This, in turn, dramatically reduces the time before seafloor information can be made available to managers, stakeholders, and the public. Importantly, this approach also enables web users to view actual footage from locations of interest within weeks of survey completion (*see www.mbnms-simon.org/other/moreLinks/whats_new_mac.php*).

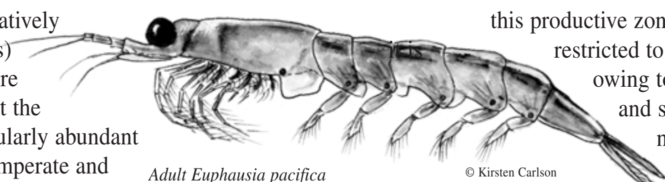
The ability to map seafloor habitats within our sanctuaries and the creatures that inhabit them will help managers better protect these habitats, plants, and animals. Further, the knowledge of what is present today will provide the foundation to monitor future changes in these important resources.

– Tara Anderson
U.S. Geological Surveyand NOAA Fisheries

Open Ocean and Deep Water Systems



Krill: It's What's for Dinner



Adult Euphausia pacifica

© Kirsten Carlson

Euphausiids, or krill, are relatively small (two to four centimeters) shrimp-like crustaceans that are broadly distributed throughout the world's oceans and are particularly abundant in the productive waters of temperate and polar regions. The majority of the eighty or so krill species feed predominantly on phytoplankton – small unicellular organisms capable of photosynthesis. In addition, most krill migrate diurnally, spending daylight hours clustered in aggregations at depth (up to several hundred meters) and rising to the surface at night to feed.

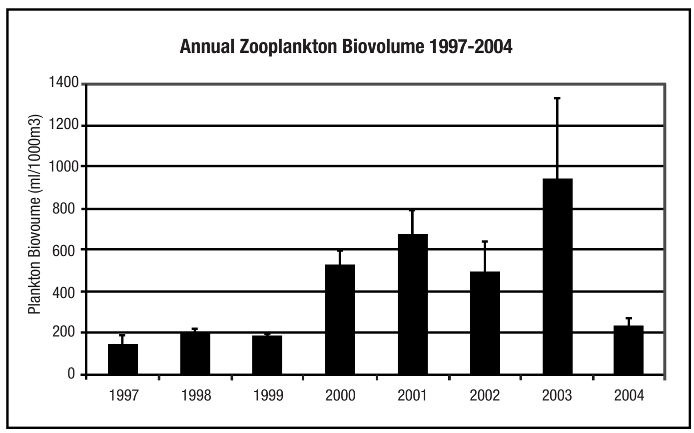
Within the coastal upwelling systems of the Northeast Pacific, krill are key players in pelagic food webs. In particular, they are important forage for a number of commercially valuable species (market squid, salmon, rockfishes, hake, and sardine) as well as several species of seabirds (Cassin's Auklet, Sooty Shearwater, and Common Murre) and marine mammals (humpback, fin, and blue whales). Krill are relatively large compared to other grazing zooplankton, which makes them directly accessible to these predators. Indeed, the blue whale – the largest animal to have ever lived – feeds almost exclusively on krill.

Several species of krill may be found within the waters of the Monterey Bay National Marine Sanctuary, but two species – *Euphausia pacifica* and *Thysanoessa spinifera* – are typically the most abundant. *E. pacifica* is found in deeper waters associated with the continental slope and open ocean regions, while *T. spinifera* is more common in waters associated with the outer continental shelf and continental slope. Both undergo strongly seasonal patterns of reproduction and growth within sanctuary waters. Peak larval production occurs in the spring and early summer, when phytoplankton abundance is typically highest.

The newly hatched larvae occupy the surface waters (<100 meters) and drift with the prevailing currents as they rapidly grow. Individuals typically develop to the juvenile stage within two months of hatching, and adult status can be attained in as little as four to five months. In years when upwelling persists into late summer, this new generation may reproduce in the early fall, but usually, the surviving adults overwinter and complete the cycle the following spring.

Krill distributions within the sanctuary also appear to have a seasonal pattern. During the spring and early summer, strong coastal upwelling results in the offshore advection (movement) of nutrient-rich water. This results in a broad zone of high phytoplankton abundance and krill, particularly larvae and juveniles. As upwelling-favorable winds subside in the late summer and fall, this productive zone collapses coastward, until by winter restricted to a relatively narrow band. Adults, owing to their deeper day time distributions and superior swimming capability, may not be subject to the same forcing mechanisms, and their abundance is consistently higher in the nearshore (<40 kilometers) region.

Krill populations within the sanctuary also appear to fluctuate on interannual – and even longer – time scales. We have been monitoring total zooplankton and krill abundance within the Monterey Bay region since 1997. This period has included both the large 1997-98



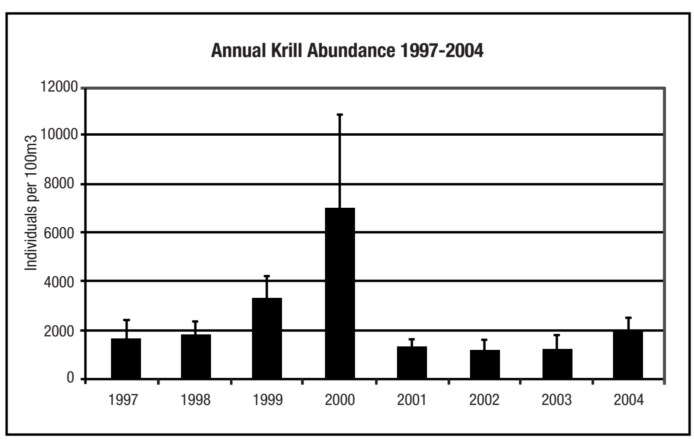


Figure 1. Mean (+ se) annual zooplankton biovolume (top panel) and krill abundance (bottom panel) collected in net samples taken within the Monterey Bay region between 1997 and 2004